MINERAL SOLUBILITY

Minerals differ in their tendency to dissolve in water. This concept is of importance when applied to repository rocks and minerals. Solubility, as measured in the laboratory, is the amount of mineral that will dissolve in a fixed amount of water, at a certain temperature, and is a property unique to each mineral composition. In a natural system, the solubility of any mineral is a function of the composition of the liquid surrounding it. Only rarely will that liquid be pure water. If a mineral in a rock dissolves, it leaves behind an open space, which increases the porosity of the rock. Permeability may be increased as minerals dissolve and connections between pores are widened.

In the following activity you will use commonly available ionic solids (solids which, when dissolved, yield a solution of cations and anions) to demonstrate a range of solubilities of single minerals.

Directions: Answer the following questions before beginning your experiment.

Purpose:

What is the purpose of this experiment?

(The purpose of this experiment is to learn how to determine the solubility of a mineral and to compare the solubility of a single mineral in solution to that of several minerals.)

Hypothesis:

Which of the four compounds listed in the Materials (next page) do you expect to be the most soluble. Why?
Which do you expect to be the least soluble. Why?

(Answers will vary. Encourage students to explain their answers.)

Materials:

Epsom salts ($MgSO_4 \cdot 7H_2O$)
table salt (NaCl)
sodium bicarbonate ($NaHCO_3$) (baking soda)
plaster of paris ($CaSO_4 \cdot 1/2\ H_2O$)
8 oven safe glass containers (100 mL or larger)
funnel
filter paper (coffee filters will work)
oven
balance (capable of weighing to 0.1 g)

Procedures:

1. Label two containers for each mineral. One will be A, the other B. (Example: Epsom salts A, Epsom salts B, etc.)

2. Fill each container in set A with 50 to 250 mL (0.1 - 0.5 pints) of tap water. Each container should have a different volume of water. Record the volume for each mineral in Table 1. It is important that you accurately measure and record the volume of water that you use.

3. Weigh the empty labeled containers in set B. Record these masses in Table 1 as M_1.

4. Add approximately 1 Tablespoon of the Epsom salts to the appropriate container in set A. Stir the solution to dissolve the Epsom salts. Continue adding Epsom salts 1 Tablespoon at a time and stirring until solid mineral remains on the bottom of the container and will not dissolve. The solution is now saturated with Epsom salts.

5. Pour the saturated solution through the funnel lined with filter paper into the correspondingly labelled, empty container in set B.

6. Repeat steps 4 and 5 for table salt, sodium bicarbonate, and plaster of Paris.

7. Put the containers in set B, now holding the saturated solutions, in an oven capable of maintaining approximately 95 °C (approximately 200 °F) overnight. Avoid oven temperatures of 100 °C or greater. You do not want the liquid to boil as solutions may splash over the sides and be lost from your final mass measurement.

8. When all of the water has evaporated and the containers have been cooled to room temperature, weigh the containers. Record these masses in Table 1 as M_2.

9. Find the mass of the dissolved mineral by subtracting the mass of the containers in set B (M_1) from their mass with the remaining dissolved mineral after drying (M_2). Record the results in Table 1 as “Mass Mineral.”

10. Solubility is expressed in terms of grams of mineral dissolved in 100 mL (0.2 pints) of water. Calculate the solubility of each of the pure minerals in this exercise and record your answers as Solubility in Table 1.

Observations:

Table 1. Single Mineral Solubilities

Mineral of Water	Volume Containers Set B, M_1	Mass Containers Set B, M_2	Mass Mineral $M_2 - M_1$	Mass g/100mL	Solubility
Epsom Salts					*71.0 at 20°C*
Table Salt					*35.7 at 0°C*
Sodium Bicarbonate					*6.9 at 0°C*
Plaster of Paris					*0.3 at 20°C*

Conclusion:

1. Compare your calculated values to the standards given by your teacher. Are there any major differences between your calculated values and those supplied by your instructor? If so, can you suggest an explanation for the differences?

   (Answers will vary. Encourage students to come up with an explanation of any observed differences.)

2. If your oven temperature was too hot and your solutions began to boil, how might the outcome of your experiment be affected?

   (Solutions may bubble and some liquid containing dissolved mineral might splash out of the container if the solution boiled. M_2 would be lower and so would the solubility.)

3. If you did not measure and record the volumes of water that you used accurately, how might the outcome of your experiment be affected?

   (It would be difficult to calculate an actual solubility if the amount of water were unknown. A volume greater than that recorded would indicate greater solubility; a volume less than recorded would show less solubility.)

4. If you add too much solid mineral to your solutions, how might the outcome of your experiment be affected?

   (It would not be affected since the amount dissolved will not change. There will only be more undissolved mineral at the bottom of the container.)

5. What sources of error did you observe in your experiment? What effect did error have on the outcome of your experiment?

   (Answers will vary. Encourage students to consider questions 2, 3, 4 in answering this question.)

6. What information would you need to determine the solubility of minerals in the proposed repository rock?

   (The types of minerals surrounding the repository.)

Common Ions

+2	+1	-1	-2
Mg^{2+}	Li^{+}	Cl^{-}	S^{2-}
Ca^{2+}	Na^{+}	OH^{-} (hydroxide)	SO_4^{2-} (sulfate)
Sr^{2+}	K^{+}	HCO_3^{-} (bicarbonate)	CO_3^{2-} (carbonate)
Ba^{2+}	H^{+}		

7. Use the table of common ions shown on the previous page to determine the cation and anion found in a solution including the minerals listed below.

Mineral	Formula	Cation	Anion
Epsom Salts	$MgSO_4 \cdot 7H_2O$	Mg^{2+}	SO_4^{2-}
Table Salt	$NaCl$	Na^+	Cl^-
Sodium Bicarbonate	$NaHCO_3$	Na^+	HCO_3^-
Plaster of Paris	$CaSO_4 \cdot 1/2\ H_2O$	Ca^{2+}	SO_4^{2-}

8. Why is the solubility of a rock important in siting a repository?

(Solubility is related to permeability. If the minerals in a rock dissolve, the spaces left behind increase the porosity and probably the permeability of the rock. This may increase the possibility of radionuclide migration.)

9. Water, moving through a rock of uniform composition, will initially dissolve some minerals. As the water travels farther through the rock, its ability to dissolve minerals decreases and eventually becomes zero. Why?

(Because it eventually cannot carry another single ion and no more complex ions are possible.)